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(54) Method and device for the heat treatment of substrates

(57) Method and device for the heat treatment of flat substrates, wherein the substrates are positioned in the vicinity of a heated, essentially flat furnace body extending over the surface of the substrate. In order to provide a reproducible treatment when treating a number of substrates successively, the temperature of the furnace body is measured so close to the surface adjacent to the substrate that the withdrawal of heat from the furnace body by the substrate can be detected. The introduction of each substrate takes place at a point in time when the temperature measured in this way is, within certain limits, equal to a desired initial treatment temperature T_{trig}.

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Description

[0001] The present invention relates to a method for the successive heat treatment of a series of flat substrates such as semiconductor wafers, according to the preamble of Claim 1.

[0002] A method of this type is generally known in the prior art. With the known method it is customary that the energy supply to the heating means is controlled such that the measured temperature of the furnace body is substantially constant and has a desired value. When a number of substrates are subjected to a heat treatment one after the other, heat is withdrawn from the furnace body on that side of the furnace body adjacent to the substrate. In the course of some time a fall in the temperature of the furnace body will be detected by the temperature sensor. As a response to this, the energy supply to the heating means will be increased to such an extent that the furnace body again reaches the desired temperature. In view of the relatively high thermal capacity of the furnace body, this is a process that proceeds slowly and it can be some time before stable conditions have been established, in particular in those cases where the thermal capacity of the furnace body is so high and the treatment time so short that the temperature of the furnace body has still not been restored at the end of the treatment of a substrate. When a subsequent substrate has been loaded, heat is again withdrawn from the furnace body and in this way the temperature deviation can become increasingly greater for an initial number of substrates to be treated before it is finally restored as a result of the slow progression of the control process. The substrates subjected to treatment during this period will have received a non-uniform heat treatment. In actuality these differences in heat treatment can be even greater than appears from the measured values produced by the temperature sensor. This temperature sensor is usually located within the furnace body, some distance away from that surface of the furnace body adjacent to the substrate. The heat, on the other hand, is withdrawn via this surface of the furnace body adjacent to the substrate. Falls in the temperature of the furnace body of 10° or more are possible at the surface or in the immediate vicinity of the surface. This is, of course, undesirable.

[0003] In the case of some heat treatments according to the prior art, after the substrate has been positioned in the vicinity of the furnace body there is a waiting period, until a stable, desired temperature has been established, after which the actual treatment, for example the deposition of a layer with the aid of plasma enhanced chemical vapour deposition, starts. A shorter or longer temperature stabilisation time at the start of the treatment is no problem here. However, in some heat treatments the entire temperature-time-profile (thermal budget) plays an important role, especially when the treatment temperature is higher than approximately 500 °C. Imposing a thermal budget on the substrates can even be the sole purpose of the treatment, without the formation of a layer on the substrate during the treatment. In such cases controlled and reproducible heating of the substrates is just as important as a reproducible treatment temperature. In other words: it is important to achieve a thermal budget that is identical for all substrates when subjecting substrates to heat treatment. In principle, positioning the substrates in the vicinity of a relatively massive, heated furnace body is an extremely suitable method for this purpose, provided the disadvantages described above can be avoided.

[0004] The aim of the present invention is to provide a method and an device for heat treatment of flat substrates which avoid the disadvantages described above and which achieve an identical heat treatment for successive substrates.

[0005] This aim is achieved with the method described above by the characterising measures of Claim 1.

[0006] In this way an identical starting situation is achieved for each substrate to be treated, which appreciably increases the reproducibility of the treatment. In a further development of the invention, after the substrate has been moved some distance away from the heated furnace body on completion of the heat treatment it is moved into the vicinity of an essentially flat cooling body, so that cooling also takes place in a rapid and controlled manner.

[0007] The method described above can be carried out in various ways, in particular with regard to the control of the power supply to the heating means. For instance, it is possible in so-called "open loop control" to supply a constant power to the heating means and, at the point in time when the treatment of substrates starts, so to increase the power supply that the increase in the power supply compensates for the heat withdrawn from the furnace body by the substrates. It is also possible in "closed loop control" to control the power supply in such a way that the temperature measured by the temperature sensor is constant. Both in the case of"open loop control" and in the case of"closed loop control" the control can be so adjusted that during the treatment of substrates the average temperature measured over time is somewhat higher than that in a state of rest. The result of this is that following treatment and removal of a substrate the temperature sensor indicates the desired temperature again within a shorter period and the introduction of the following substrate can start at an earlier point in time.

[0008] The method described above is in particular suitable for subjecting substrates to a heat treatment in a so-called "floating wafer reactor", as described in US Patent 6 183 565 B1 in the name of the Applicant. In this floating wafer reactor flat substrates are brought one by one and successively between two essentially flat furnace bodies parallel to the substrate, after which the furnace bodies are moved towards one another and positioned a short distance away from the wafer and the wa-

fer is supported and held in place by gas streams, directed in opposing directions, issuing from these furnace bodies, without mechanical contact. With floating wafer reactors of this type it has proved possible to provide very rapid heating or cooling of the wafers without the wafers being damaged. As a result of the very rapid heating, wafers can also be treated very rapidly in succession. According to a variant of the invention, substrates are treated in a treatment chamber in which, in addition to the heat treatment chamber, there is also a cooling station and a transport system for the substrate. The temperature of the substrate is lowered very rapidly in the cooling station under controlled conditions.

[0009] The invention also relates to an device for the heat treatment of a series of substrates, comprising a heating body with a flat surface for accommodating said substrate adjacent to said surface, controllable heating means for heating said heating body, at least one temperature sensor some distance away from said flat surface, for measuring the temperature in said heating body, connected to first control means for controlling the power supply to said heating means, transport means for positioning substrates in the vicinity adjacent to said heating body, holding them in this position and removing them therefrom, second control means for controlling the transport means, wherein the temperature sensor is arranged near to said flat surface of the heating body in such a way that withdrawal of heat from the heating body by the substrate is detected and the first and second controllers are constructed such that moving each of said substrates into the heating body can take place only after a desired state has been reached, which desired state is determined by the temperature measured by said temperature sensor in said heating body as a function of time and wherein the removal of each of said substrates takes place before said desired state has been achieved again. According to an advantageous embodiment, this second controller comprises a low level control for controlling the motors of the transport means and a high level control for transmitting control signals to the low level control and receiving clearance signals. These clearance signals originate from sensors or from other control means and indicate that the device is ready for the next treatment action and that the device is in a safe condition for this further treatment action. One of these clearance signals originates, directly or indirectly, from the first controller for controlling the power supply to the heating means and is transmitted when the desired state has been reached within certain limits, determined on the basis of the signal transmitted by the said temperature sensor. The device can be provided with software to perform calculations on the signal transmitted by the temperature sensor in order to establish whether the desired state has been reached. This software can be operational in the first controller or a controller connected to this. When this clearance signal has been received and when any other requisite clearance signals are present, the high level control of the second control means gives a start signal to the low level control, which low level control causes the transport means to execute the desired movements. An unsafe condition of the device is determined by various sensors, such as sensors that indicate the position or presence of the substrate or of the transport means. If an unsafe condition is found while movements are being executed by the transport means, the high level control can transmit an interrupt to the low level control. As a result of this configuration, unspecified time delays in the substrate transport means as a consequence of checks carried out by the control are avoided and the transport of the substrates will take place as reproducibly as possible.

[0010] The heating means can be arranged in or on the furnace body or directly adjacent to the furnace body. It is also possible for the heating means to be arranged some distance away from the furnace body and for the heating means to comprise lamps or an induction coil.

[0011] The invention will be explained in more detail below with reference to the drawings. In the drawings:

Fig. 1 shows, diagrammatically, variants of "open loop" methods of control of the power supply to the heating means;

Fig. 2 shows, diagrammatically, variants of "closed loop" methods of control of the power supply to the heating means;

Fig. 3 shows, diagrammatically in cross-section, the furnace body with temperature sensors arranged therein;

Fig. 4 shows, in plan view, a reactor for the successive treatment of substrates;

Fig. 5 shows, in perspective, the transport mechanism used in the floating wafer reactor;

Fig. 6 shows, in a side view, the furnace bodies of the floating wafer reactor with mounting and movement mechanism;

Fig. 7a shows, diagrammatically, the treatment of substrates in a floating wafer reactor, with the reactor open;

Fig. 7b shows, diagrammatically, the treatment of substrates in a floating wafer reactor, with the reactor closed;

Fig. 8 shows the controller for controlling the transport means;

Fig. 9 shows a graph of the changing temperature in the furnace during successive introduction and removal of a number of substrates;

Fig. 10 shows a graph of the changing temperature in the furnace body during the successive introduction and removal of a number of substrates, in which the "first substrate effect" can clearly be seen.

Fig. 11 shows a graph of the changing temperature in the furnace body during successive introduction and removal of a number of substrates, where the time of introduction is determined on the basis of the measured and extrapolated temperature.

[0012] In the method according to the invention there is a controller for controlling the power supplied to the heating means. This controller will be provided with inputs for receiving signals from temperature sensors and an output for transmitting a signal that determines the power supplied to the heating means. This controller can be any controller customary known in the art.

[0013] In Fig. 1, the "open loop" method of control of the power supply to the heating means, the abscissa shows the time and the ordinate the temperature of the furnace body and the power supplied to the heating means. At the start, the heat treatment device is in a state of rest, in which a constant power P_0 is supplied to the heating means and the furnace body is at an essentially constant temperature T_0 corresponding to that power. Two variants of control according to the invention are shown. In the case of variant a the power is increased before treatment of substrates starts. As a consequence of this the temperature of the furnace body will increase. When a desired temperature T_{trig}, has been reached, the first substrate is positioned in the vicinity of the heated furnace body and held in the vicinity of the heated furnace body for a certain period, after which the substrate is moved some distance away from the heated furnace body and cooled. There is then a waiting period until the temperature measured by the temperature sensor has once again reached the desired value, T_{trig}, at which point in time the next substrate is positioned in the vicinity of the furnace body. The same procedure is repeated until all substrates to be treated have been subjected to the heat treatment. The variant indicated by b differs from the a variant in that the power supplied to the heating means is increased at the same time as the first substrate is positioned in the vicinity of the furnace body. In variant b T_{trig} is equal to T_0, whilst in variant a T_{trig} is higher than T_0. In Fig. 2 the "closed loop" method of control of the power supply to the heating means is shown. In this figure, once again, the abscissa shows the time and the ordinate the temperature of the furnace body and the power supply to the heating means. At the start, the heat treatment device is in a state of rest, in which a power P is supplied to the heating means and controlled in such a way that the furnace body is at a constant temperature T_0. Two further variants of the control according to the invention are shown. In variant a the temperature set point of the furnace body is raised to the value T_1 before the treatment of substrates starts. As a consequence of this the temperature of the furnace body increases. When a desired temperature, T_{trig}, has been reached the first substrate is positioned in the vicinity of the heated furnace body and held in the vicinity of the heated furnace body for a specific period, after which the substrate is moved some distance away from the heated furnace body and cooled. There is then a waiting period until the temperature measured by the temperature sensor has once again reached the desired value, T_{trig}, at which point in time the next substrate is positioned in the vicinity of the furnace body. The same procedure is repeated until all substrates to be treated have been subjected to the heat treatment. In variant b the temperature set point remains the same and is $T_0 = T_1 = T_{trig}$. Even with good adjustment of the temperature controller, usually of the PID type, variant b will be significantly slower than variant a.

[0014] In the variants in Fig. 1 and variant a in Fig. 2 a temperature gradient, averaged over time, is established over the furnace bodies, the temperature on the side of the furnace body facing away from the substrate being higher than the temperature on the side adjacent to the substrate. As a result a heat flow, averaged over time, is established in the direction of the substrate, which heat flow compensates for the heat taken up by the substrates. Instead of supplying additional heat only at the point in time when the heat withdrawn by the substrate is measured, as a result of establishing a gradient over the furnace body the requisite amount of heat is in fact already on its way. As a result, much more rapid restoration of the temperature of the furnace body on the side facing the substrate is obtained than is the case with conventional temperature control.

[0015] In Fig. 3 several temperature sensors 134 are indicated, arranged close to that surface of the furnace body 130 adjacent to the substrate 21. It is essential for the invention that the temperature sensors are arranged close to that surface of the furnace body adjacent to the substrate, a distance of less than 5 mm away and preferably a distance of approximately 2 mm or less away. As a result, the fall in temperature as a consequence of the withdrawal of heat from the furnace body will be adequately detected. In the above, reference has always been made to a single sensor, but in practice there will usually be a need for several temperature sensors arranged distributed over the heated furnace body in order to be able to ensure that the furnace body has the desired temperature over the entire surface. The temperature signal that is used to start the substrate transport can then be the average of all temperature signals originating from sensors that have been arranged in the vicinity of the surface of the furnace body. The control can also be implemented in such a way that the device is not cleared for loading a substrate if the temperature differences detected between the various sensors are too high. As an alternative, the condition can be that all sensors must have reached a temperature that deviates from the desired temperature T_{trig} by less than a determined value. In practice this will amount to the same thing. A comparable measure will apply when a heated furnace body is arranged on either side of the substrate, both furnace bodies being provided with one or more temperature sensors.

[0016] The heating means can be constructed in such a way that they comprise several groups of individually controlled heating means, distributed over different parts or zones of the furnace body. At least one temperature sensor will have to be available for each group. In the case of control in accordance with the "closed loop"

principle, each temperature sensor will have to have been arranged in the vicinity of that surface of the furnace body which is adjacent to the substrate. The advantage of the "closed loop" control is that the desired temperature will be achieved for each part of the furnace body that is provided with a separate group of heating means. In the case of the "open loop" control this is not necessarily the case and the power will have to be adjusted for each group in order to achieve a desired temperature. In the case of this "open loop" control it is not necessary to provide every zone of the furnace body with a temperature sensor arranged according to the invention, but it is possible to suffice with at least one temperature sensor, arranged close to the surface adjacent to the substrate. However, the other sensors are needed to establish correct adjustment of the constant power for each group, in such a way that a uniform temperature is obtained.

[0017] In Fig. 4 a system for the treatment of a substrate is indicated by 1. This system is delimited by the walls of a reactor chamber 2. In a manner that is not shown in more detail, a substrate can be introduced into or removed from a feed/discharge station, indicated by 3, through a closure in the wall. The substrates are transported with the aid of a rotary transfer mechanism 4, the details of which can be seen in Fig. 5. 5 indicates a heating furnace according to the invention, whilst 6 indicates a cooling station.

[0018] Substrates to be treated are transferred at the feed/discharge station to the transfer mechanism 4 and are introduced first into furnace 5, where they are subjected to a rapid rise in temperature and then a heat treatment, followed by cooling in a controlled manner in the cooling station 6.

[0019] The transfer mechanism is shown in Fig. 5. This mechanism consists of a part 7 rigidly fixed to the housing and a rotary shaft 8, driven in some way or other, provided with three arms 9, on each of which supports 10 for substrates are arranged. A ring 11 is fitted around each of the supports 10. This ring is so constructed that the substrate lies within it and loss of heat at/ supply of heat to the substrate is essentially uniform over the entire surface on exposure to a cooling body or, respectively, a heated furnace body, that is to say there is no temperature deviation close to the edge of the substrate. Although three transport arms 9, each provided with a support 10 and ring 11, have been shown in both Figs 4 and 5, the transport mechanism can also be equipped with fewer arms. Since according to the invention it is necessary to wait until the furnace body has reached the desired initial treatment temperature again, after removing the previous substrate, before the next substrate is positioned in the vicinity of the furnace body, in practice it is possible for a single transport arm to suffice.

[0020] In Fig. 7 the furnace shown in Fig. 6 is shown diagrammatically in cross-section. Upper block 13 and lower block 14 are in a housing 23 that is provided with a flap 22 that can be opened for loading and subsequently removing a substrate 21. Lower block 14 and upper block 13 can be moved towards one another by lifting rods 27 and 28. Block 13 is made up of a furnace body 130, an insulating jacket 131, a heating coil 132, arranged on the inside of the insulating jacket, and an outer jacket 133. Similarly, block 14 is made up of a furnace body 140, an insulating jacket 141, a heating coil 142, arranged on the inside of the insulating jacket, and an outer jacket 143. Furnace body 130 is provided with at least one temperature sensor 134 and furnace body 140 is provided with at least one temperature sensor 144. According to the invention these temperature sensors are arranged close to that surface of the furnace bodies which is adjacent to the substrate. In a preferred embodiment of the invention, furnace body 130 is also provided with a temperature sensor 135 that is arranged close to that side of the furnace body that faces away from the substrate. In a similar manner furnace body 140 can be provided with a temperature sensor 145 arranged close to that side of the furnace body that faces away from the substrate. Gas is supplied both from the lower furnace body 140 through openings 24 and from the upper furnace body 130 through openings 25. Gas is discharged through opening 26. When a substrate is introduced upper block 13 and lower block 14 are in a position in which they have been moved apart. After the substrate has been introduced the blocks are moved towards one another by lifting rods 27 and 28 in such a way that the distance between each of the substrate surfaces and the adjacent surfaces of the furnace bodies is 1 mm or less. The substrate is held in a stable position by the gas streams issuing from the openings 24 and 25, without further mechanical support being required.

[0021] The presence of temperature sensors 134 and 144 close to the substrate on the one hand and of temperature sensors 135 and 145 close to the heating means on the other hand makes it possible to use a cascade temperature controller. This is a control that makes use of the temperature sensors in both positions. The advantage of such a control is that because the temperature sensors are close to the substrate a correct temperature can be achieved in this location and the withdrawal of heat is measured rapidly, whilst as a result of the temperature sensors close to that side of the furnace body located opposite the substrate, the temperature remains readily controllable and, for example, it is possible to avoid the outside of the furnace body reaching too high a temperature, followed after some time by the inside of the furnace body reaching too high a temperature. For a cascade control of this type temperature sensors 135 and 145 do not necessarily have to be arranged close to that side of the furnace body that is facing the heating means. The temperature sensors can, for example, be arranged more in the interior of the furnace body, but the distance to that surface of the furnace body which is adjacent to the substrate will be greater than the distance to that side of the furnace body facing

the heating means.

[0022] Part of the control for the device is shown in Figure 8. In this figure a first controller, to which temperature sensors 134 and 144 are connected, has been indicated by 70. A second controller 60 is connected to the first controller and functions to control the transport means. The second controller comprises the high level control 50 and the low level control 40.

[0023] High level control 50 is provided with inputs 51, 52, 53 and 54 for receiving clearance signals. At least one of these clearance signals originates, directly or indirectly, from the first controller 70 and indicates that the furnace body has a desired temperature, within certain limits, close to the surface adjacent to the substrate. Drives 41, 42, 43 and 44 for driving the transport means are connected to low level control 40. The transport means comprise substrate transport means and furnace body transport means. High level control 50 transmits data on the movements to be executed to control 40. These movements are executed only after receipt of a start signal originating from control 50. This start signal is transmitted when all applicable clearance signals have been received by high level control 50. The movements are executed after transmission of the start signal to the low level control. Possible unsafe situations are verified not by control 40 but by control 50. If any unsafe situation is detected by one of the clearance signals dropping out while executing the movements, control 50 then transmits an interrupt to control 40, on receipt of which the movement is discontinued. As a result of not burdening control 40 with a wide variety of verifications, which can lead to small, but undefined, delays, the movements are executed as reproducibly as possible, which also benefits the reproducibility of the heat treatment.

[0024] It will be clear that for the exact embodiment of the control several possibilities exist. For example it is possible to control the power supply to the heating means by the first controller 70. Also a separate controller can be used to that end. The first and second controller can be connected directly through a main controller. All controllers can be incorporated in a single controller.

[0025] Finally, in Fig. 9 a graph is shown of the actual change in temperature as a function of time. The continuous line indicates the temperature and the dotted line the power taken up. In this case so-called "open loop control" is being used, that is to say a constant power is supplied to the heating means. This power supplied is increased somewhat before a substrate is introduced. The consequence of this is that the measured temperature rises. Once a specific value has been reached, in this case 975 °C, a substrate is positioned in the vicinity of the furnace body and a reduction in temperature takes place. After the substrate has been removed, the next substrate is not introduced until the temperature sensor again indicates 975 °C. It will be clear that the increase in the power that has been set at the start of the successive treatments has to be matched to the power taken from the furnace body by the substrates. If too small an increase in the power is set, it will take too long before the temperature has been restored again. If too high an increase in the power is set, the temperature can then reach too high a value. In Fig. 9 it can be seen that if no further substrates are introduced after the successive introduction of ten substrates, whilst the power remains set at the higher value, the temperature reaches a value higher than that desired. It can be seen from Fig. 9 that each of the ten substrates has been subjected to as uniform as possible a thermal budget, as a result of which optimum reproducibility of heat treatments can be achieved.

[0026] Although the introduction of the substrates to be treated when a desired temperature T_{trig} is reached subjects the substrates to an essentially reproducible temperature treatment, on closer consideration a problem is nevertheless found to arise. This problem is outlined in Fig. 10. In this figure the points in time at which wafers #1, #2, #3 and #4 are loaded are indicated by arrows. The point in time at which a wafer is unloaded is indicated by a vertical line. In the example shown the temperature of the furnace body has been set at 1000 °C and the wafers are each loaded when the initial treatment temperature of 1000 °C has been reached again. When the first wafer is positioned adjacent to the furnace body heat is withdrawn from the furnace body. This withdrawal of heat is detected by the temperature sensors and transmitted to a controller to control the power supply to the furnace body. The heating means have, however, been placed some distance away from the boundary surface of the furnace body facing the wafer. A temperature gradient will be established between the heating means and the boundary surface of the furnace body facing the wafer, so that, averaged over time, a heat flow will be set up to compensate for the heat withdrawn from the furnace body by the wafers. Wafer #2 is loaded when the temperature has reached 1000 °C again. If no substrate were to be loaded the temperature would rise to a value above 1000 °C because of the inertia of the system. In Fig. 10 it can be seen that it takes some time before a constant pattern is established. Thus, the temperature is not constant at the point in time when a wafer is unloaded. It can be seen that a reproducible pattern is established only after a few wafers. The thermal budget to which a wafer is subjected is, of course, not determined exclusively by the initial treatment temperature measured, but also by the temperature gradient that exists in the furnace body at the point in time when the heat treatment starts. It can be concluded from the fact that the temperature profile in Fig. 10 is not reproducible that the temperature gradient in the furnace body is not constant. According to a particular embodiment of the invention it is possible to compensate for this. For this purpose a method as illustrated in Fig. 11 is proposed. In this figure the points in time at which wafers #1, #2, #3 and #4 are loaded are

again indicated by arrows. The point in time at which each wafer is unloaded is also indicated by a vertical line. According to the more detailed variant of the invention, the temperature of the furnace body, as measured close to the boundary surface facing the wafer, is extrapolated over the future time. In the example in Fig. 11, the period over which the extrapolation is carried out is equal to the treatment time $t_{process}$. The desired state that has to be reached before a wafer is introduced is in this case not a desired constant value of the measured temperature but the temperature at which the extrapolated temperature, averaged over the time for which the treatment is to be carried out, has a desired constant value. In the example in Fig. 11 this desired value is 1000 °C and a linear extrapolation is made. Wafers #2, #3 and #4 are thus loaded at the points in time when the value of the extrapolated temperature, averaged over the time $t_{process}$ for which the treatment is to be carried out, is 1000 °C. For a linear extrapolation this temperature will be reached precisely halfway through the indicated period. This means that, compared with wafer #1, wafer #2 is loaded at a somewhat lower measured temperature and is unloaded at a somewhat higher extrapolated temperature. It can also be seen from Fig. 11 that the actual measured temperature at the point in time when wafer #2 is unloaded is higher than that for wafer #1. For wafers #3 and #4 the measured temperatures at the time of loading are a little lower again than for wafer #2 and at the time of unloading are somewhat higher than for wafer #2. It has been found that a treatment carried out in accordance with this more detailed development yields a more reproducible result than when a constant value is taken for the initial treatment temperature. The time that is needed for loading a wafer can also be taken into account in this development. If the time that is needed for loading a wafer is t_{load}, the extrapolation can be carried out over a period t_{load}, so that there is a desired temperature at the point in time when the wafer is placed in the vicinity of the heating body, adjacent to the latter. This is of importance particularly when the loading time is of the same order of magnitude, or longer than, the treatment time. The extrapolations are realised by the device. Finally, both developments can be combined, so that the extrapolation is carried out over a period $t_{load} + t_{process}$ and the wafer is loaded at the point in time when the extrapolated temperature, averaged over the period t_{load}, $t_{load} + t_{process}$, has the desired value. For the extrapolation good results are obtained with a linear extrapolation in accordance with the least squares method, where the period that was used as starting point for the extrapolation was approximately one fifth of the period between loading successive wafers. It is, of course, possible to use higher order polynomials for the extrapolation, although this increases the risk of instability in the calculation.

[0027] Although the invention has been described above with reference to a preferred embodiment, it must be understood that this preferred embodiment serves only for illustration. For instance, the control of the power supply to the heating means can be implemented in a way other than those described. The substrate can also be supported in various ways during the treatment, both mechanically and non-mechanically. The substrate can also be placed at different distances in the vicinity of the furnace body. A further variant is that the substrate is brought into contact with the furnace body and optionally is pressed against the furnace body to promote the thermal contact. These variants will be obvious to a person skilled in the art and fall within the scope of the appended claims.

Claims

1. Method for the successive heat treatment of a series of flat substrates, such as semiconductor wafers, wherein

   - these are placed adjacent to, and essentially parallel to, a heating body having a flat boundary surface facing the substrate,
   - the temperature in said heating body is measured at a location therein that is so close to the boundary surface that after the substrate has been placed in position the withdrawal of heat from the heating body by the substrate is measured at that location,
   - each of said substrates is placed in the vicinity of said heating body, adjacent to the latter, only after a desired temperature measured in that location has been reached;
   - and an amount of heat is supplied to said heating body such that the temperature measured at said location during the successive heat treatment of the series of substrates has an essentially constant value averaged over time,

   characterised in that

   - each of said substrates is removed from said heating body before said desired temperature, measured at said location, is reached again.

2. Method according to Claim 1, wherein said desired temperature has a constant value by means of which an initial treatment temperature T_{trig} is defined.

3. Method according to Claim 1, wherein said desired temperature is determined by extrapolating the temperature measured at said location over the period t_{load} required for placing said substrate in the vicinity of said heating body, adjacent to the latter, or the period $t_{process}$ for which the heat treatment is

to be carried out, during which said substrate remains in the vicinity of said heating body, adjacent to the latter, or the sum of the two said periods.

4. Method according to Claim 3, wherein said measured temperature has a desired constant value after extrapolation over said period t_{load}.

5. Method according to Claim 3, wherein said measured temperature has a desired constant value after extrapolation and averaging over the period $t_{process}$ of the heat treatment to be carried out.

6. Method according to Claim 3, wherein said measured temperature has a desired constant value after extrapolation over the period $t_{load} + t_{process}$ and averaging over the period t_{load}, $t_{load} + t_{process}$.

7. Method according to Claims 3 - 6, wherein the extrapolation is a linear extrapolation.

8. Method according to Claims 3 - 7, wherein the period that is taken as starting point for the extrapolation is of approximately the same magnitude as the period over which the extrapolation is carried out.

9. Method according to one of the preceding claims, wherein said specific location where the temperature of said heating body is measured is a distance of less than 5 mm away from said flat surface.

10. Method according to one of the preceding claims, wherein said specific location where the temperature of said heating body is measured is a distance of less than 2 mm away from said flat surface.

11. Method according to one of the preceding claims, wherein a constant amount of heat is supplied to said heating body and the heat supplied during treatment of the substrates is set to a higher value than during rest.

12. Method according to one of Claims 1 - 10, wherein during the treatment of the substrates the heat supplied to the heating body is controlled in accordance with a constant value T_1 of the temperature of the heating body.

13. Method according to Claim 12, wherein the initial treatment temperature T_{trig} is equal to the value T_1 of the temperature of said furnace body during the treatment of the substrate.

14. Method according to Claim 12, wherein the initial treatment temperature T_{trig} is higher than the temperature of the heating body T_0 before the start of treatment of the substrates but is lower than the desired temperature T_1 of the furnace body during the treatment of the substrates.

15. Method according to one of Claims 1 - 10 and/or 12 - 14, wherein the temperature in said heating body is measured in two different locations located some distance away from said flat surface and heat is supplied using a control according to the cascade principle, wherein the measurement of the temperature at one of said locations is coincident with the measurement of the initial treatment temperature.

16. Method according to one of the preceding claims, wherein after said substrate has been removed from the vicinity of the heating body the substrate is positioned in the vicinity of a cooling body.

17. Method according to one of the preceding claims, wherein said substrate is arranged between the flat surfaces of first and second heating bodies which are located opposite one another and are each provided with individual heating means, wherein the temperature of said second heating body is measured at a location spaced from said flat surface of said second heating body in such a way that withdrawal of heat from the heating body by the substrate is detected and that positioning of each substrate in the vicinity of said second heating body takes place at approximately the same time as positioning of each substrate in the vicinity of the first heating body, at a point in time at which the temperature of the second heating body measured in this way is, within certain limits, equal to a desired initial treatment temperature T_{trig}.

18. Device for the heat treatment of a series of substrates, comprising a heating body with a flat surface for accommodating a substrate adjacent to said surface, controllable heating means for heating said heating body, control means, at least one temperature sensor, arranged in said heating body near to said flat surface such that withdrawal of heat from said heating body by said substrate is detected, wherein said temperature sensor is connected to said control means, transport means for positioning substrates in the vicinity of said heating body, adjacent to said flat surface, and removing substrates therefrom, wherein said transport means are connected to said control means, **characterised in that** said control means comprises digital control means, being provided with extrapolation software for extrapolating over a time interval the temperature measured by said temperature sensor, and that said control means is arranged in such a way that said positioning each of said substrates in the vicinity of said heating body is able to take place only if the temperature extrapolated over said time interval has reached a desired temperature value.

19. Device for the heat treatment of substrates according to Claim 18, wherein said at least one temperature sensor is arranged in the heating body a distance of less than 5 mm away from said flat surface.

20. Device for the heat treatment of substrates according to Claim 19, wherein said at least one temperature sensor is arranged in the heating body a distance of less than approximately 2 mm away from said flat surface.

21. Device according to one of Claims 18 - 20, wherein the second controller comprises a low level control for controlling the transport means and a high level control, wherein said high level and low level controls are implemented in such a way that after a start signal has been transmitted by the high level control to the low level control, the low level control causes the transport means to execute a number of movements in accordance with a preprogrammed pattern.

22. Device according to one of Claims 18 - 21, comprising a further heating body, wherein said heating body and said further heating body can be moved with respect to one another to accommodate said substrate between them and to release said substrate, wherein said further heating body is provided with further heating means controlled by said controller, of comparable construction to the first furnace body and connected to the controller, and wherein, when substrates have been introduced, the two heating bodies are arranged on opposite sides of the substrate parallel to the substrate so that they can move towards one another.

23. Device according to one of Claims 18 - 22, provided with a cooling body with a cooling chamber for accommodating the substrate, wherein the cooling body is arranged in the extension of the transport direction of the transport means for positioning the substrate in the vicinity of the heating body.

Fig 1a

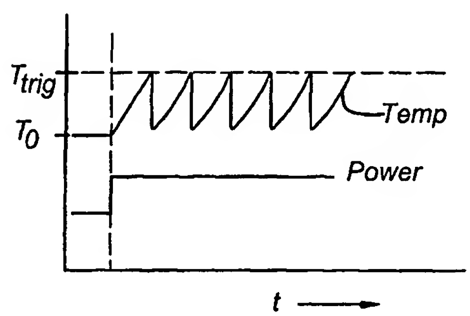

Fig 1b

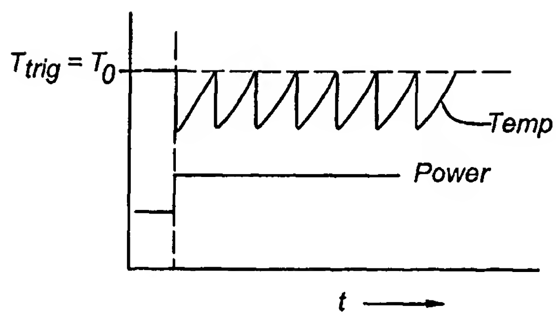

Fig 2a

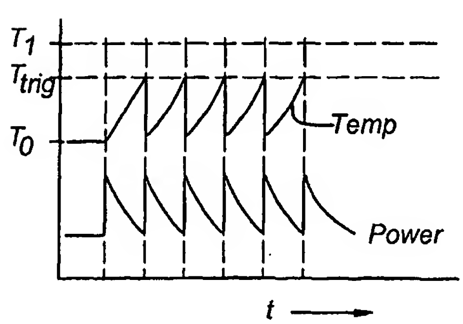

Fig 2b

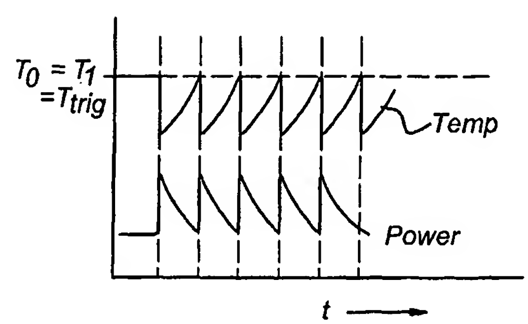

Fig 3

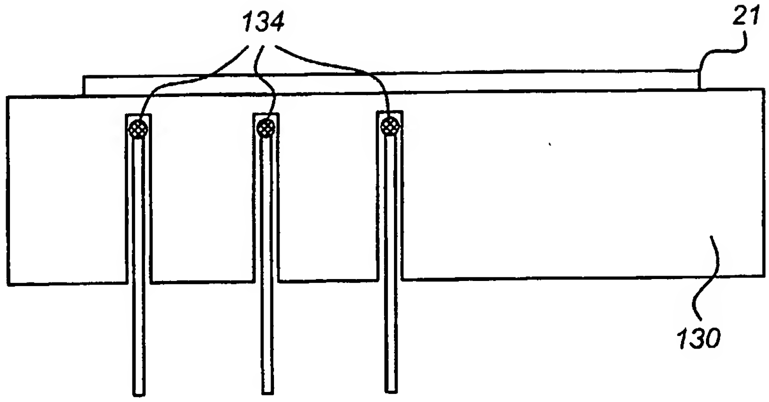

Fig 4

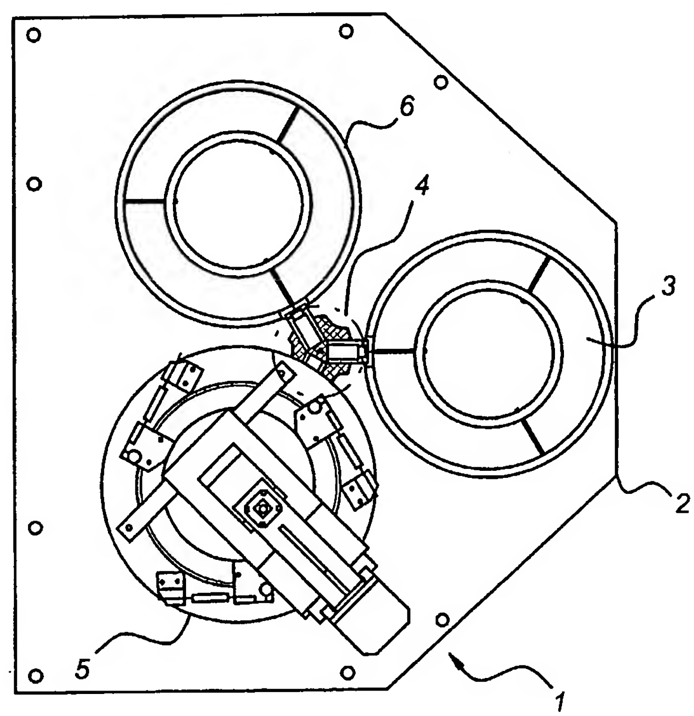

Fig 5

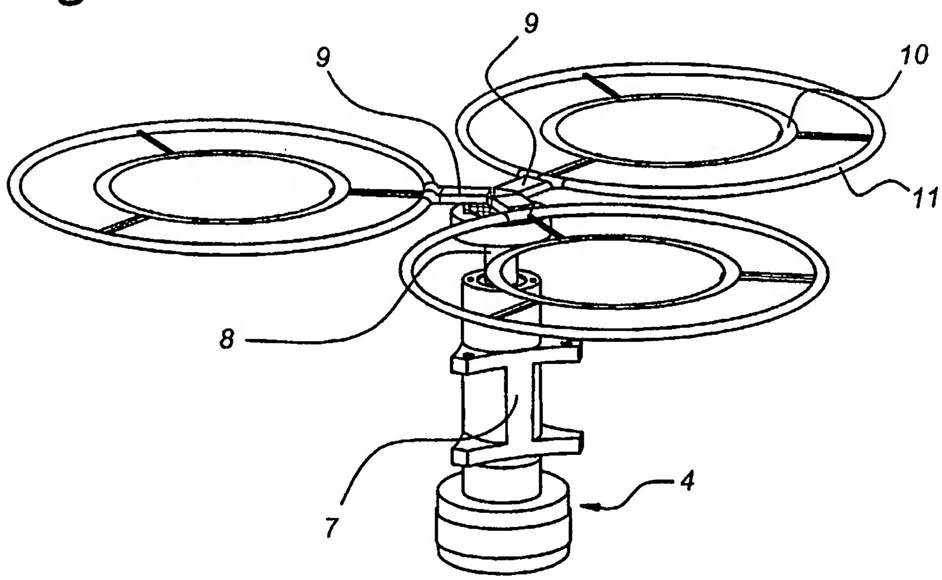

Fig 6

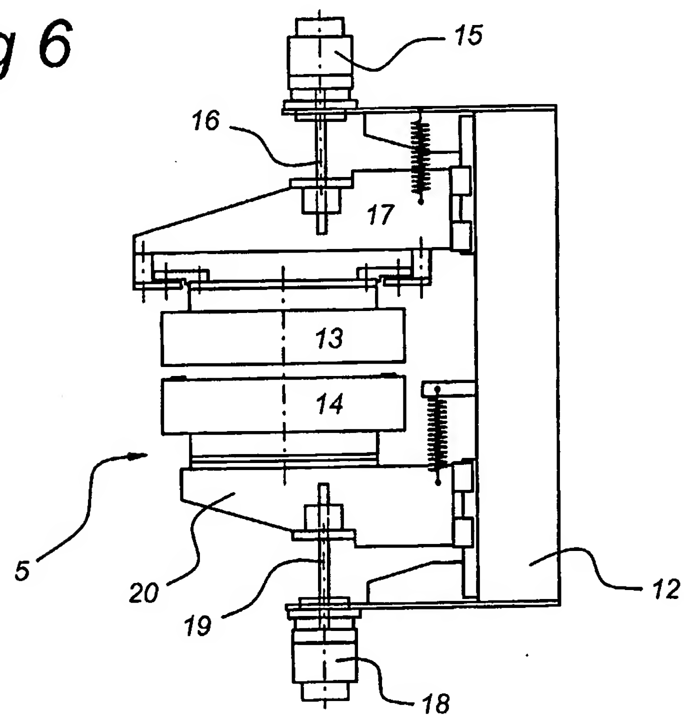

Fig 7a

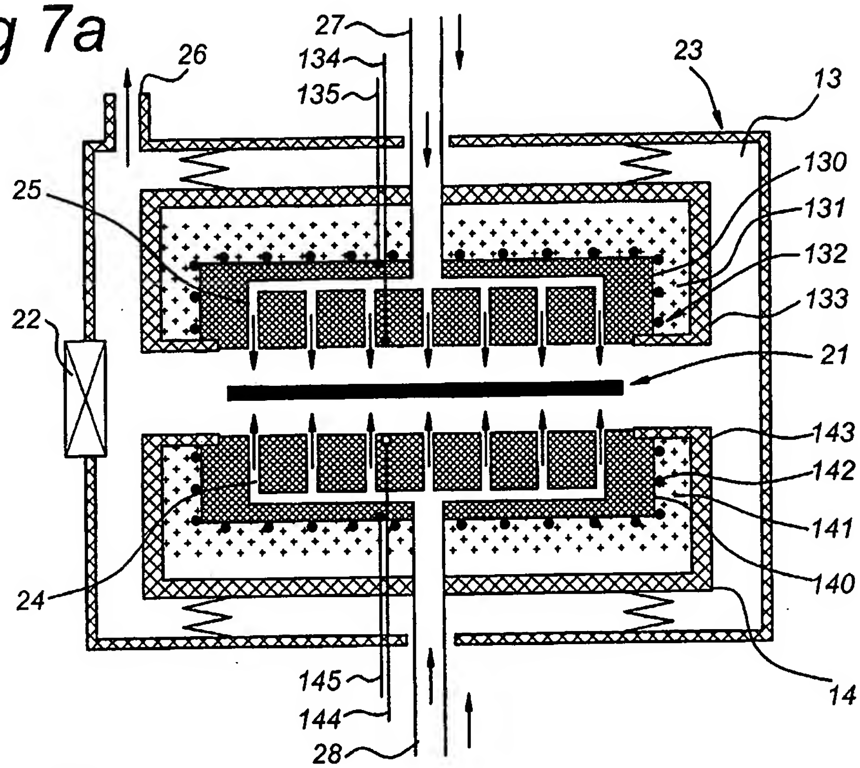
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Fig 7b

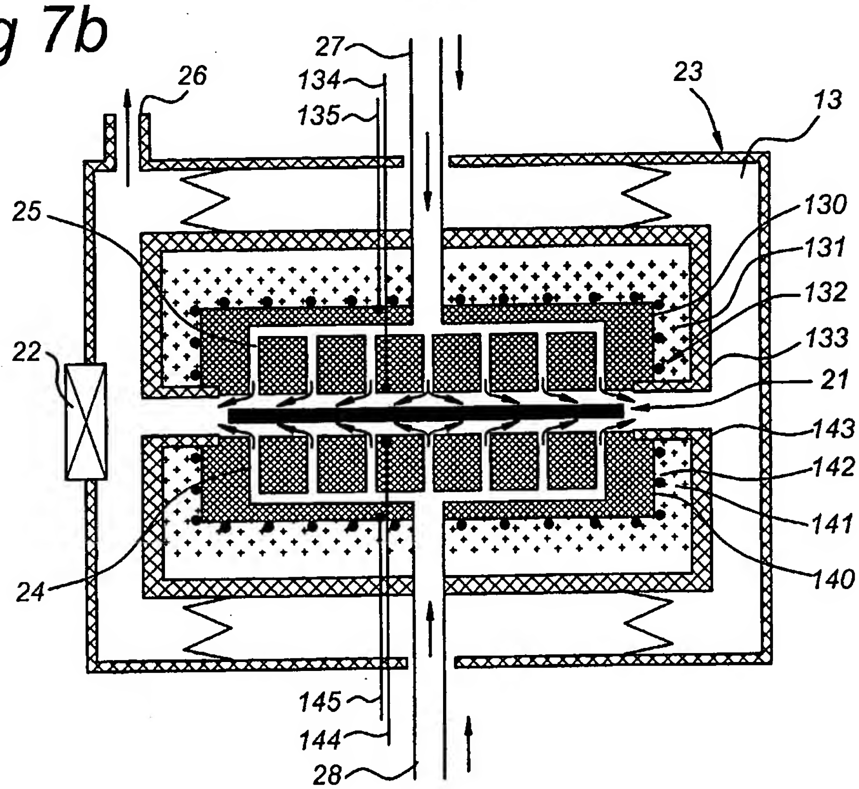
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Fig 8

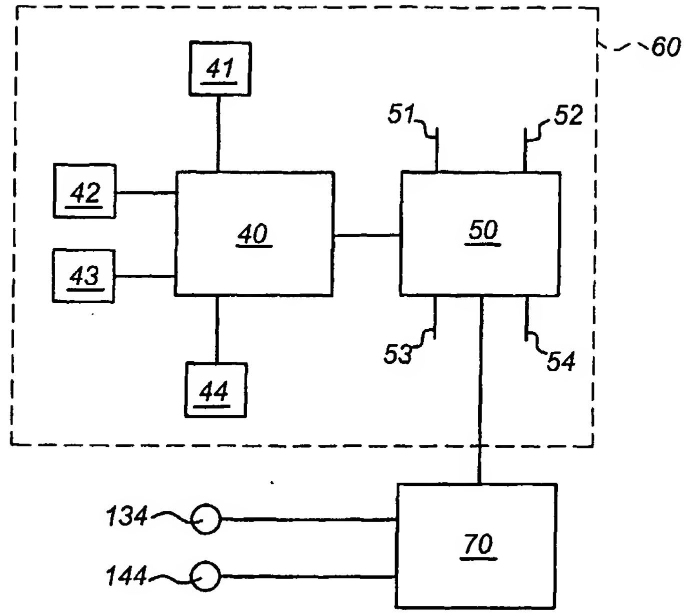
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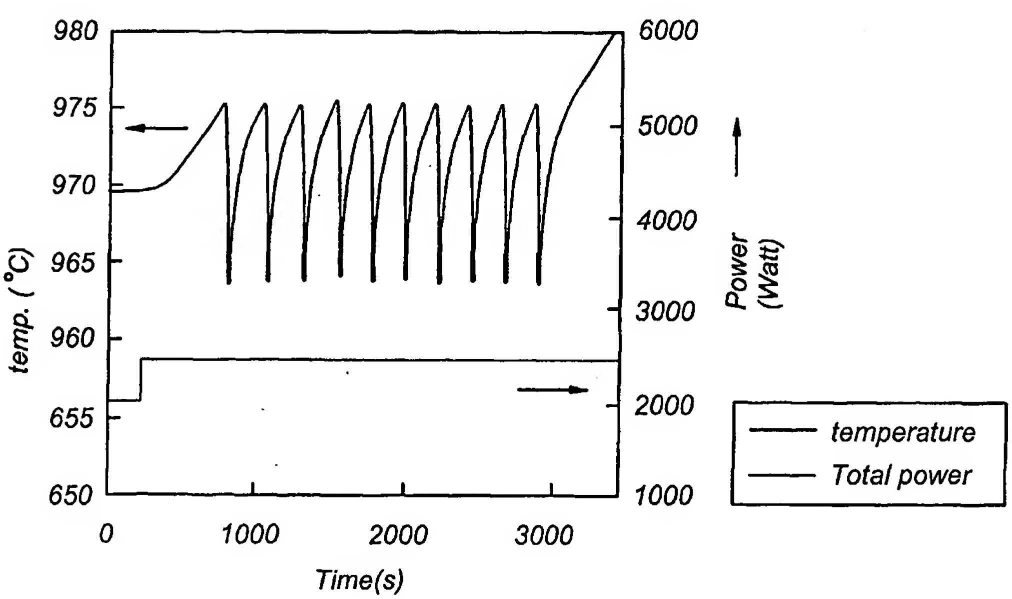
Fig 9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970
965
960
655
650
temp. (°C)
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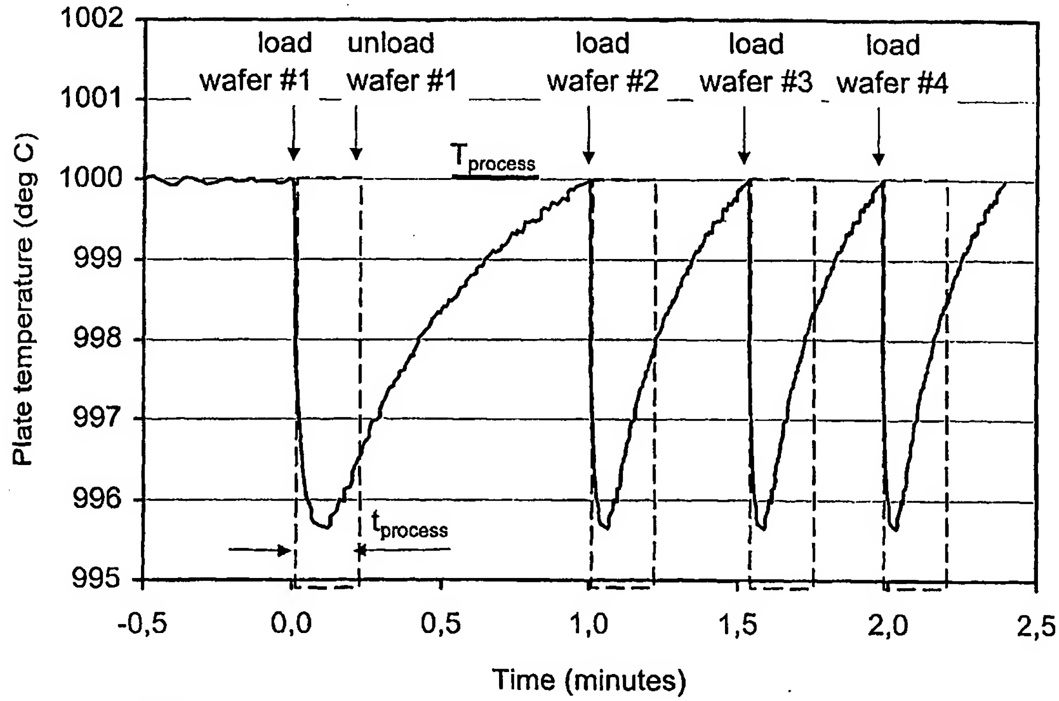
5000
4000
3000
2000
1000
Power (Watt)
0
1000
2000
3000
Time(s)
temperature
Total power

Fig 10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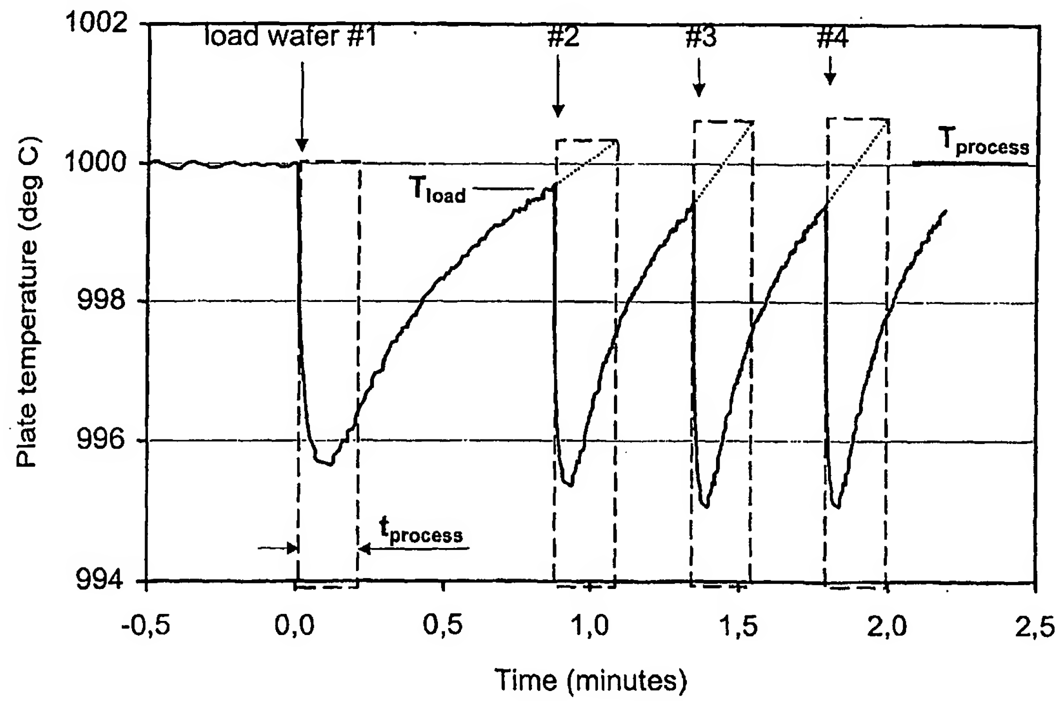
wafer #1
unload
wafer #1
load
wafer #2
load
wafer #3
load
wafer #4
$T_{process}$
$t_{process}$
Plate temperature (deg C)
1002
1001
1000
999
998
997
996
995
-0,5
0,0
0,5
1,0
1,5
2,0
2,5
Time (minutes)

Fig 11


load wafer #1
#2
#3
#4
$T_{process}$
T_{load}
$t_{process}$
Plate temperature (deg C)
1002
1000
998
996
994
-0,5
0,0
0,5
1,0
1,5
2,0
2,5
Time (minutes)